

SALEM HARBOR

MASSACHUSETTS

SURVEY

(REVIEW OF REPORTS)



**CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.**

APRIL 20, 1956

53

NOT FOR PUBLIC RELEASE

SURVEY
REVIEW OF REPORTS

SALEM HARBOR
MASSACHUSETTS

SYLLABUS

The Division Engineer finds that prospective benefits are sufficient to justify further improvement of Salem Harbor, Massachusetts. He recommends the modification of the existing project to provide for a channel 32 feet deep at mean low water and generally 300 feet wide extending 1.5 miles from deep water in the outer harbor to the limit of the existing Federal project, about 1,500 feet off Salem Terminal Wharf, and for the removal of Mann Rock to the same depth, contingent upon certain measures of local cooperation including provision by local interests of an adequate access channel of the same depth to the existing terminal, all as shown on the maps accompanying this report. The estimated cost to the United States is \$1,100,000 for new work and \$3,000 for annual maintenance required.

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CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

NEDGW

20 April 1956

SUBJECT: Survey (Review of Reports) of Salem Harbor,
Salem, Massachusetts

TO: Chief of Engineers, Department of the Army,
Washington 25, D. C.

AUTHORITY

1. This report is submitted in compliance with the following resolution adopted June 17, 1948 by the Committee on Public Works of the House of Representatives, United States Congress:

"RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE HOUSE OF REPRESENTATIVES, UNITED STATES, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review the reports on Salem Harbor, Massachusetts, printed in House Document Numbered 701, Seventy-sixth Congress, Third Session, with a view to determining if it is advisable to modify the existing project in any way at this time."

2. Pursuant to the above authorization, a favorable preliminary examination report was submitted by the Division Engineer March 23, 1950 recommending a survey be made to determine the advisability and cost of any improvements which might be found to be justified and the local cooperation required. The report of the Board of Engineers for Rivers and Harbors was favorable and recommended that a survey be made.

SCOPE OF SURVEY

3. A review report of survey scope was assigned to the New England Division by letter of the Chief of Engineers dated May 18, 1950.

4. In the preparation of this report, a detailed hydrographic survey consisting of soundings and probings was made, from which the character of the harbor bottom and estimated quantities to be dredged were determined. Available maps, commercial statistics and other data pertaining to the harbor have been studied. A public hearing was held

at Salem, Massachusetts on September 22, 1949, and information obtained therefrom is described in Paragraphs 26 to 29 inclusive, of this report. The information obtained from the public hearing is further supplemented by recent contacts with local interests and correspondence submitted by them, and all additions or changes in improvements requested subsequent to the public hearing are incorporated and considered in this report.

DESCRIPTION

5. Salem Harbor is located about 12 miles northeast of Boston Harbor and 11 miles southwest of Cape Ann. It is the largest of four harbors, Manchester, Beverly, Salem and Marblehead, which are arms of a large irregular indentation in the shore of Massachusetts Bay. Salem Harbor extends in a southwesterly direction from the southwestern end of the indentation, the harbor proper being in the cove between Marblehead peninsula and Salem Neck. The City of Salem lies at the head of the harbor. The inner harbor averages about $3/4$ mile in width and about $1-1/2$ miles in length from the entrance at Naugus Head. More than one-half the area of the inner harbor is shallow, with depths ranging from 1 to 6 feet at mean low water. Numerous scattered shoals having depths of 4 to 6 feet also serve to limit other areas to shallow draft-vessels. Directly in front of the city lie extensive flats with the 6-foot depth curve located 1,000 to 2,000 feet from the high water line. Within the inner harbor is an area of about 130 acres with depths of 12 to 25 feet at mean low water. There is also good anchorage for vessels in the outer part of the outer harbor westward of Bowditch Ledge and northward and eastward of Great Haste Island where there are depths of 30 to 40 feet, and in a second anchorage to the eastward of the entrance to Beverly Harbor and northward of Middle Ground and the adjacent seaplane restricted area, where there are depths of 21 to 36 feet.

6. The water approach to the center of the City of Salem is provided by South River. The river is entered from the west side of Derby Wharf and extends about 3,000 feet to the head of navigation at Lafayette Street. An improved channel in South River formerly provided depths of 10 feet at mean low water from the inner harbor to a point opposite the lower end of Pickering Wharf, thence 8 feet deep for an additional distance of 1,400 feet upstream, thence 6 feet to the head of navigation. Subsequent shoaling, however, has reduced the usable depth of the channel at the entrance to less than 8 feet and proportionately reduced upstream depths.

7. The approach to Salem Harbor is by channels which pass between the islands, shoals, and ledges which lie between Marblehead Neck and Great Misery Island. The three principal channels are South Channel, which is an extension of Marblehead Channel and leads along the northern shore of the Marblehead peninsula directly to the entrance



to Salem Harbor proper; Cat Island Channel, which is the middle channel and leads from the sea in a northerly direction between Cat Island and Eagle Island to the outer harbor; and the Main Ship Channel, which is the most northerly channel and leads in a westerly direction between Bakers and Great Misery Islands from the open ocean to the outer harbor. Deep-draft vessels use the Main Ship Channel. This is a natural channel with a depth of more than 30 feet, extending to within one mile of the entrance of the inner harbor at Naugus Head. From Naugus Head the main ship channel continues about 1.7 miles to the Salem Terminal Wharf, with a controlling depth of 24 feet and a width of 300 feet. This extent of the Main Ship Channel includes the improved 25-foot Federal Channel extending 1,500 feet from the 25-foot depth curve with a width of about 300 feet to a point about 1,500 feet from the Salem Terminal Wharf. A channel and basin in extension of the Federal Channel have been dredged by local interests to a depth of 25 feet for a distance of about 1,500 feet to the Salem Terminal Wharf.

8. The mean range of tide in Salem Harbor is 9.0 feet, and the spring range is 10.4 feet. The locality is shown on United States Coast and Geodetic Survey Charts, Numbered 240, 241 and 1207, and on the plan accompanying this report.

TRIBUTARY AREA

9. Salem, the county seat of Essex County, is one of the oldest residential communities in Massachusetts, and at one time was one of New England's greatest seaports. It is the trading center for a population of over 184,000 living in the North Shore area extending from Lynn to Cape Ann. Nearby cities and towns include Marblehead, Swampscott, Peabody, Danvers and Beverly. In 1950 Salem had a population of 41,880. As of January 1, 1954, the assessed property valuation amounted to \$57,545,720. The generation of electric power at the Salem plant of the New England Power Company represents a major unit of the New England power pool. Manufacturing, the principal industry of Salem, employs about 25 percent of all workers employed in gainful occupations. Among the principal articles manufactured are electric and radio apparatus, boots and shoes, leather, and foundry and machine products.

10. Salem is served by the Boston and Maine Railroad and by an excellent system of highways. It is located 16 miles from downtown Boston. Several bus and truck companies operate over the highways, providing direct service to Boston, Lawrence, Lowell, and other cities.

BRIDGES

11. There are no bridges over Salem Harbor nor over its

entrance channel. South River is crossed by a municipally-owned highway bridge at Congress Street, about 300 yards downstream from Lafayette Street, the head of navigation. This bridge was authorized by an Act of the Massachusetts Legislature approved August 4, 1915 and July 2, 1917. It consists of a single swing span over the channel, with a clear opening for navigation of 43 feet and vertical clearance in a closed position of 13 feet at mean low water and of 4 feet at mean high water. The desired improvement does not extend to this bridge and would entail no bridge alteration.

UNDERWATER UTILITIES

12. Salem Harbor is crossed by two sewer lines which pass under the Main Ship Channel. They are operated by the South Essex Sewerage District, with headquarters in Salem, and dispose of sewerage from the cities of Salem, Beverly, Peabody and the town of Danvers. The lines are described as follows:

(a) A 54-inch cast-iron pipe force main extending easterly from Juniper Point to a point about 300 feet southerly from Great Haste Island, thence northeasterly about 1,500 feet to the outlet. The section below the Main Ship Channel is laid with the top of the pipe 35 feet below the plane of mean low water. The line was completed in 1928.

(b) A 30-inch cast-iron pipe force main extending from Juniper Cove, passing about 200 feet northeasterly of Abbot Rock Beacon and connecting with the 54-inch pipe at a point about 300 feet southerly from Great Haste Island. The section below the Main Ship Channel is laid with the top of the pipe 31 feet below the plane of mean low water. The line was completed in 1905.

PRIOR REPORTS

13. Salem Harbor has been the subject of other reports. Pertinent data with reference to the reports are shown in the following tabulation:

Published In	Type of Report	Work Considered and Recommendation
House Executive Document No. 60, 41st Congress, 3rd Session - 1871	Survey	Remove projecting rock and clear channel for 8-foot depth to the entrance to the South River - Favorable
Senate Executive Document No. 25, 42nd Congress, 3rd Session - 1873	Survey	Dredge a 300-foot wide channel, 1,730 feet long, 8 feet deep from deep water to the entrance of South River. Construct a seawall and breakwater for the protection of Long Point - Favorable

PRIOR REPORTS - Continued

<u>Published In</u>	<u>Type of Report</u>	<u>Work Considered and Recommendation</u>
House Executive Document No. 71, 48th Congress, 2nd Session - 1885	Preliminary Examination	Construct a jetty from the mainland to deep water for the protection of Long Point - Unfavorable
House Executive Document No. 28, 51st Congress, 1st Session - 1890.	Preliminary Examination and Survey	Clear approach channel to South River to original dimensions, 300 feet wide at entrance, 150 feet wide off Derby Wharf Light, 8 feet deep; extend channel, reducing width to 100 feet near inner end of Derby Wharf, and from this point excavate a channel 50 feet wide, 6 feet deep to head of navigation - Favorable
House Document No. 303, 58th Congress, 2nd Session - 1904*	Preliminary Examination	Dredge a 10-foot channel 5,700 feet long from the Harbor to head of South River, 300 feet wide at the entrance, narrowing to 200 feet wide at Derby Wharf, and thence full width of channel between wharves - Favorable
House Document No. 112, 70th Congress, 1st Session - 1927*	Preliminary Examination and Survey	Provision of a channel 25 feet deep, 300 feet wide and 1,500 feet long, and removal of shoal near Abbot Rock Beacon - Favorable
House Document No. 701, 76th Congress, 3rd Session - 1940*	Preliminary Examination and Survey	Channel 30 feet deep to Salem Terminal Corporation. Extend present 10-foot channel into South River. Bredge branch channels and anchorage basins. Dredge slips on South River - Partially favorable

PRIOR REPORTS - Continued

<u>Published In</u>	<u>Type of Report</u>	<u>Work Considered and Recommendation</u>
Unpublished 1950	Preliminary Examination	Recommended survey to determine the advisability of modifying the existing project to provide greater depths in the Main Ship Channel and in the South River Channel.-- Favorable

*H.D. 303/58/2, 112/70/1, 701/76/3 form the basis of the existing project.

EXISTING CORPS OF ENGINEERS PROJECT

14. Salem Harbor was first improved under the River and Harbor Act of March 3, 1873, which authorized the dredging of an approach channel to South River, 1,730 feet long, 300 feet wide, and 8 feet deep at mean low water. This work was completed at a cost of \$25,000 in April 1875.

15. The River and Harbor Act of September 19, 1890 provided for clearing out the approach channel to South River to the original dimensions, as dredged in 1873 - 1875, 300 feet wide at the entrance and 150 feet wide off Derby Wharf Light, 8 feet deep at mean low water, and for extending the channel with the same depth up the South River, reducing its width gradually to 100 feet near the inner end of Derby Wharf, and from that point dredging a channel 50 feet wide and 6 feet deep to the head of navigation at Lafayette Street. This improvement was completed in June 1894, at a cost of \$27,368.66.

16. The total cost for the above described previous projects has been \$52,368.66 for new work, with no costs for maintenance.

17. The existing project provides for a 25-foot channel in the main harbor, 300 feet wide, extending about 1,500 feet from the 25-foot depth curve in the Main Ship Channel to within about 1,500 feet of the Salem Terminal Wharf; for the removal to the same depth of a shoal near Abbot Rock Beacon; for a channel in the approach to and in the South River, 10 feet deep at mean low water from that depth in the harbor to the upstream end of Pickering Wharf, 300 feet wide at the entrance, gradually narrowing to 200 feet at Derby Wharf

Light, thence 150 feet wide to the bend at the outer end of Derby Wharf, thence about 90 feet wide to the bend near Central Wharf, thence 50 feet to the upstream end of Pickering Wharf; and for a branch channel on the east side of Derby Wharf 8 feet deep, 100 feet wide and approximately 700 feet long, widening to a basin of the same depth 500 feet long and 200 feet wide. The River and Harbor Act of March 3, 1905 (House Document No. 303, 58th Congress, 2nd Session), provided the 10-foot channel to a point opposite Derby Wharf Light; the River and Harbor Act of July 3, 1930 (House Document No. 112, 70th Congress, 1st Session), provided the 25-foot channel; and the River and Harbor Act of March 2, 1945 (House Document No. 701, 76th Congress, 3rd Session), provided the extension of the 10-foot channel in South River to Pickering Wharf and the 8-foot channel and basin.

18. The 10-foot channel has been partly dredged, the section to a point opposite Derby Wharf Light having been dredged in 1906. This same section was restored to project depth in 1915. Dredging of the 25-foot channel was completed in 1931 and no maintenance has been performed to date, present controlling depths in the project channel being 24 feet. The work remaining to complete the existing project is the extension of the 10-foot channel into South River and the dredging of the 8-foot channel and mooring basin on the east side of Derby Wharf. The costs to date under the existing project have been \$57,130.93 of which \$48,087.91 was for new work and \$9,043.02 was for maintenance. Of these costs, \$36,587.91 was for new work costs of the 25-foot channel. Total costs to date on all projects have been \$109,499.59, of which \$100,456.57 was for new work and \$9,043.02 for maintenance. The latest (1954) approved estimate for annual cost of maintenance is \$6,000. This estimate is more than adequate, the 25-foot channel not having required maintenance until recently since its completion in 1931.

LOCAL COOPERATION ON EXISTING AND PRIOR PROJECTS

19. The River and Harbor Act of July 3, 1930, authorized the 25-foot channel in accordance with House Document No. 112, 70th Congress, 1st Session, which provided that local interests shall give assurances satisfactory to the Secretary of the Army that they will dredge and maintain a connecting channel leading to the Salem Terminal Wharf, having a depth of not less than that provided in the Government channel, and that they will maintain a suitable berthing space at the Wharf to a depth of not less than 28 feet at mean low water. These requirements were met in 1931, the Salem Terminal Company dredging 110,000 cubic yards at a cost of \$65,000.

20. The River and Harbor Act of March 2, 1945 authorizes the extension of the 10-foot channel in South River and the 8-foot channel and basin in accordance with House Document No. 701, 76th Congress, 1st Session, which provides that local interests shall furnish assurances satisfactory to the Secretary of the Army that landing facilities open to all on equal terms will be provided and main-

tained, and shall hold the United States free from damages that may result from the channel improvement. These requirements have not been met.

OTHER IMPROVEMENTS

21. Salem Harbor has been improved by the Commonwealth of Massachusetts, by local and private interests, and by the United States Navy, as well as improvement for general navigation by the Federal Government. In 1909, the Commonwealth of Massachusetts supplemented work completed in 1906 by the United States by extending the 8-foot channel from the lower end of the Pickering Coal Company's Wharf for a distance of 1,400 feet and a width of 50 to 75 feet, to within 200 feet of the head of navigation. Between 1913 and 1915, the Commonwealth further supplemented this improvement by deepening the channel to 10 feet at mean low water for a width of 90 feet from a point about opposite Derby Wharf Light to the upper end of Central Wharf. The total expenditure by the Commonwealth of Massachusetts for improvement and maintenance of this work was \$13,462.66. In 1947, State and local interests shared equally in the dredging of a 5-foot channel and anchorage in Palmer Cove at a cost of about \$53,500, and an 8-foot channel to Dion's Boat Yard, at a cost of about \$8,200. Again in 1954, the State dredged a 6-foot channel and an 8-foot turning basin in Palmer Cove at a cost of \$33,106.56, and under the same contract dredged an 8-foot channel and basin leading to Dion's boatyard in South Salem at a cost of \$16,935.12. In 1947 and 1948, the Department of the Navy dredged a basin 15 feet deep on the east side of Central Wharf, had sheet piling driven for a distance of 300 feet along the east wall, and dredged a basin 10 feet deep along the west side of the wharf.

22. In 1924-25 the Salem Terminal Corporation constructed its pier, and dredged an approach channel there to 22 feet deep, with a berth at the pier 734 feet long, 26 feet deep. The dredging included removal of 271,000 cubic yards of material at a cost of \$130,000. The dredged material was deposited hydraulically on shore, creating 9 acres of filled land. In 1931 the Salem Terminal Company deepened their channel in fulfillment of requirements of local cooperation as indicated in Paragraph 19 above. In 1951, the New England Power Company dredged a 25-foot channel from the Federal Channel to the Salem Terminal Wharf, and an area in front of the wharf to a depth of 31 feet, removing 254,815 cubic yards of material at a cost of \$231,156.53. In addition to the dredging, wharf construction was undertaken in 1951 at a cost of \$410,000. The total local expenditures in connection with port development directly related to deep-draft shipping have amounted to \$836,000, including the \$65,000 expended in dredging in 1931 in fulfillment of requirements of local cooperation.

TERMINAL AND TRANSFER FACILITIES

23. The extensively developed water-front of Salem Harbor, which includes South River, is a little more than one mile in extent and is owned for the most part by private individuals. There are 9 wharves in this area, two of which belong to the National Park Service, with one of these being used by the Department of the Navy for a reserve training center. There are 9 other wharves in Salem Harbor which are located outside of the extensively developed area. The terminal facilities in Salem Harbor are listed in the following table:

TERMINAL FACILITIES

Name and Location	Type of Construction	Berthing Space	Facilities	Use
<u>EXTENSIVELY DEVELOPED AREA</u>				
Sales Terminal Wharf (Harbor)	Steel bulkhead and earth fill. Bulkhead 677' long- 12" sheet piling 50' long. Wharf, timber piling and wood deck in front of bulkhead.	700 feet, 31 feet deep at mean low water.	5-ton coal unloading bridge. One 2-yd. crane. One 2-1/2 yd. crane. Railroad spur track.	Commercial. Receipt and storage of bituminous coal, fuel oil and kero- sene. Open coal storage 200,000 tons. Oil stor- age 750,000 barrels.
North Shore Petroleum Co.Inc. (Harbor)	Masonry retaining wall, solid earth fill; con- crete cap, 26'x10' timber pile extension	247 feet, dry at mean low water	None	No waterborne traffic. Receipt by truck of fuel oils and gasoline. Storage capacity 10,000 barrels.
Millers Pier (Harbor)	Open pile and timber deck	None	None	Private. Home on land end and summer house on outer end.
Derby Wharf (Oldest wharf in United States) (Harbor)	Stone retaining wall, solid earth fill.	400 feet, 6 feet deep at mean low water	None	A National Park. Operated by the National Park Service. Small area used by local lobstermen.
Central Wharf (South River)	Pile and timber retain- ing wall, solid earth fill, hard top surface	300 feet, 10 to 15 feet deep at mean low water		Owned by National Park Service. Occupied by U.S. Navy as a reserve train- ing center.
George W. Pickering Co.(South River)	Masonry retaining wall, solid earth fill, timber pile and deck extension	523 feet, 10 feet deep at mean low water	None	Commercial. Receipt and storage of petroleum products. Storage 40,000 barrels.

Salem Bay Transportation Co. (South River)	Pile and timber bulkhead, solid earth filled wharf with float and 2 ramps	100 feet	Gasoline service	Private. For recreational use. For small craft.
J.P.Langmaid and Sons (South River, above Congress St. Bridge)	Masonry, bulkhead and solid earth fill.	350 feet, 2 feet deep at low water	None	Commercial. Receipt and storage of lumber. At present inactive.
Essex County Electric Co. Wharf (South River, above Congress St. Bridge)	Masonry, bulkhead, earth fill.	500 feet long; 2 feet deep at mean low water	None	Private; open storage for about 15,000 tons of coal; no direct receipts by water.

OTHER DEVELOPED AREAS

Palmer Cove Yacht Club	None	75 feet. Approach channel 6' at mean low water; basin 8' at mean low water	1 Marine railway for 40-foot boats	Commercial. Boat storage, 45 boats capacity.
F. J. Dion Boatyard (Palmer Cove)	Timber and pile bulkhead, solid fill. 2-open pile and timber piers with narrow pile and timber catwalk and unloading ramp.	200 feet. Approach channel and basin 8' at mean low water.	2 Marine railways of 100-ton capacity each.	Commercial. For building, repairing and storing of boats. Storage, 90 boats capacity.

TERMINAL FACILITIES - Continued

Name and Location	Type of Construction	Berthing Space	Facilities	Use
<u>OTHER DEVELOPED AREAS</u>				
Walker-Cahill Pier (Juniper Cove)	Open pile and timber deck pier	100 feet	Marine railway for 40-foot boats.	Commercial. Boatyard, sales and storage, 70 boats capacity.
Welsh's Boatyard (Juniper Cove)	Open pile and timber deck pier	100 feet	Marine railway for 40-foot boats.	Commercial. Boat stor- age, 8 boats capacity.
Dunn Lobster Company (Juniper Cove)	Open pile and timber deck pier	50 feet		Commercial. Receipt of lobster catches.
Marrow Pier (Juniper Cove)	Open pile and timber deck pier	250 feet		Commercial. Receipt of lobster catches.
Salem Willows Pier	Open pile and timber deck pier	100 feet along each side		Recreational. For small boats.
Salem Willows Yacht Club	Open timber posts and deck pier	50 feet along each side	Gasoline service	Recreational. Small pleasure boats.

There are no storage warehouses at the port and no facilities for the public storage of bulk freight.

24. Analysis of the above tabulation of terminal facilities, and of the commercial statistics for Salem Harbor, clearly reveals that the overwhelming majority of the commerce of the harbor is received at the Salem Terminal Wharf. This has been a natural development, resulting in part from the location of the natural deep water channel into the harbor, and in part from expenditures by local interests of substantial sums on dredging and upon filling land and improving the terminal facilities. At the time of the adoption of the existing Federal 25-foot channel for Salem Harbor, the identity of the needs of the harbor and the needs of the then Salem Terminal Corporation was recognized, but it was believed that such a channel might be extended at some future time to serve the waterfront between the Salem Terminal Wharf and Derby Wharf. The unforeseen modern growth of oil and coal commerce, and the failure of other types of commerce to develop at Salem, however, have made it more economical to expand facilities at a single wharf which already enjoyed relatively deep water facilities, rather than to develop additional deep water terminals, with expensive berthing, handling, and storage facilities. The Salem Terminal Wharf has therefore become a "through-put", or unloading and temporary storage terminal serving other distributors of fuel as well as the owners themselves.

IMPROVEMENTS DESIRED

25. A public hearing was held at Salem, Massachusetts, on September 22, 1949, to determine the nature and extent of the modification of the existing project desired by local interests, and to afford an opportunity for all parties concerned to express their opinions and views. There were present at the hearing the representatives of the local Congressional District and representatives of the United States Navy, the National Park Service, the Commonwealth of Massachusetts, the city of Salem, Salem Chamber of Commerce, New England Power Company, the Pocahontas Fuel Company, Incorporated, the George W. Pickering Company, the Pocahontas Steamship Company, and the Boston Fuel Transportation Company, Incorporated, as well as other interested parties.

26. The improvements desired, as determined at the hearing, were the modification of the existing project to provide greater depths in the Main Ship Channel and the channel in South River. One modification desired was that the completed 300-foot wide, 25-foot deep Main Ship Channel be deepened to 30-feet and extended to within 100 feet of the Salem Terminal Wharf. A second modification desired was that the partially completed 10-foot channel in the South River be deepened to 14 feet from that depth in the harbor to the upstream end of Pickering Wharf. It was also desired that additional lighted channel markers be placed to allow safe navigation at night as well as day. The principal arguments advanced by the proponents of the improvements were concerned with the transportation of petroleum products and coal.

27. The representative of the New England Power Company stated that the operation of the new fuel burning electric generating plant located at Salem Harbor will require substantial quantities of water-borne fuel. An increase in channel depth from 25 feet to 30 feet would result in substantial savings in the cost of fuel delivered to the generating plant, since it would permit the use of modern deep draft vessels.

28. The representative of the George W. Pickering Company advocated the deepening of the South River Channel to 14 feet at mean low water from that depth in the harbor to the upstream end of Pickering Wharf. Vessel owners were stated to be increasingly reluctant to discharge cargoes at the Pickering Wharf which is now used for the receipt of distillate fuel oil. The receipt of coal has been discontinued at this wharf. The Pickering Company's interest in the Main Ship Channel stems from the fact that this company presently distributes bituminous coal from the Salem Terminal Wharf to customers throughout the area. Because of the industrial demand of the area served by this company it is important that the maximum use of the channel be made by modern deep-draft colliers.

29. The representative of the Boston Fuel Transportation Company, Incorporated, described the difficulties in navigating the South River Channel to the Pickering Wharf. The vessels of this company are restricted to the period of high water when navigating the South River. The transportation rates by water are not based on mileage but on the time involved, and as a consequence the transportation charges for Salem Harbor are equal to those for points which are at much greater distance but are not affected by tidal delays.

30. Subsequent conferences with local interests reveal that the desired improvements have undergone a change. Local interests now request that the Main Ship Channel be deepened to more than 30 feet, rather than just to 30 feet, in order to facilitate navigation of the channel to the Salem Terminal Wharf by the modern 11,000 ton colliers and T-2 type and super-tankers. Local interests prefer a depth of 35 feet, or as a second choice, 32 feet. All deep draft vessels must presently enter the channel two hours prior to high tide to insure safe transit, though not without difficulty, to the wharf. Petroleum products for general distribution and coal for the new 160,000 K.W. Electric Power Station, recently constructed adjacent to the channel, are water-borne to the Salem Terminal Wharf. There would be transportation savings if it were possible for the deeper-draft vessels to use the channel to the wharf without serious delays.

31. Local interests no longer request the deepening of the South River channel. Local interests now request merely that the South River channel be completed and maintained to the authorized project depth of 10 feet at mean low water up to the Pickering Wharf. Such completion of the 10-foot channel and its maintenance would materially aid the

present condition, since the majority of tankers now in use in this channel draw 9 to 12 feet of water. Present channel conditions allow only high water navigation by the vessels using the river to the Pickering Wharf.

32. Local interests have requested the removal of Mann Rock, although differences of opinion have been expressed as to the necessity or relative importance of its removal. This rock area, with 20 feet of water over it at low water, is located about 0.5 mile east of Juniper Point. It is nearly in the track of vessels approaching Salem Harbor, and is marked by a lighted buoy.

33. Local interests are still desirous of having additional lighted channel markers placed for night navigation. Some improvements have been made by the addition of lighted buoys marking the channel.

34. Local interests have stated that the expanding fish industry of the surrounding area has made necessary the construction of a state pier at Salem Harbor. However, no action has been taken by the Commonwealth of Massachusetts to initiate a state pier project.

COMMERCE

35. The transportation of petroleum products and coal constitute the principal items of waterborne commerce in Salem Harbor at the present time. The tonnage handled during the 10-year period 1946 through 1955 is indicated in the following tabulation:

COMPARATIVE STATEMENT OF TRAFFIC - SALEM HARBOR

Year	Commodity (tons)			Total Tonnage
	Coal	Oil	Misc.	
1946	339,580	39,994	-	379,574
1947	307,315	46,655	-	353,970
1948	334,471	39,382	-	373,853
1949	165,839	37,135	316	203,290
1950	207,039	49,335	-	256,374
1951	210,852	65,354	26	276,232
1952	385,068	257,678	119	642,865
1953	430,799	427,274	467	858,540
1954	487,326	562,000	-	1,049,326
1955	575,999	604,138	-	1,180,137

The coal commerce of 576,000 tons is more than double the average coal commerce of 1946 - 1950 inclusive, and represents an increase in annual tonnage of over 300,000 tons. The present coal commerce

is primarily due to the construction of the power plant at Salem, the former coal commerce having diminished to a fraction of its former volume. The increase in oil commerce is much more spectacular. The oil commerce in 1955 is over 600,000 tons, which is over 14 times the volume handled in 1946 - 1950 inclusive, and represents an increase in annual tonnage of over 550,000 tons. About 40 percent of this increase is due to shifting of commercial demand from coal to oil, and the remainder is due both to normal expansion in demand and to capture of a large market by reason of more direct and economical delivery in modern tankers to Salem Harbor.

36. The average oil commerce over the life of the project is estimated at 50 percent greater than present tonnage. This estimate is exclusive of the new power plant which is built to use either coal or oil. The estimates of future oil and coal commerce are based on the assumed continuation of the use of coal by the power plant. The present production of the power plant is estimated at 1,275,000,000 KWH, and it is estimated that planned plant expansion will increase this power production to 2,400,000,000 KWH in 1958, to 3,500,000,000 KWH in 1963 and to about 4,600,000,000 KWH further in the future. These expansions in plant capability and output would increase the coal commerce for the utility from about 450,000 tons at present to 835,000 tons in 1958, 1,225,000 in 1963, and 1,615,000 tons in the future. The annual coal tonnages, thus increased 385,000 tons for each power plant expansion, averaged over the life of the project represent aggregate average annual increases over present coal tonnage of 385,000 tons, 770,000 tons, and 1,025,000 tons. If the utility converted to oil, the tonnage increases would be about 75 percent of these figures.

VESSEL TRAFFIC

37. Vessel statistics for 1954 show a total of 85 vessels utilized the channel to unload or load their cargo, as shown in the following tabulation:

SALEM HARBOR, MASS.

Vessel Traffic

Draft (in feet)	1949	1950	1951	1952	1953	1954		
						coal	oil	Total
31	- -	- -	- -	- -	7	- -	1	1
30	- -	1	5	28	29	- -	12	12
29	- -	- -	4	11	22	36	15	51
28	1	8	3	7	2	4	3	7
27	3	4	- -	2	1	- -	- -	- -
26	2	- -	- -	- -	- -	- -	- -	- -
25	- -	- -	2	1	1	- -	- -	- -
24	1	15	13	- -	3	- -	31	31
23	7	2	2	2	2	- -	- -	- -
22	10	- -	- -	1	4	- -	- -	- -
21	3	- -	- -	- -	5	- -	- -	- -
20	- -	- -	- -	5	7	- -	- -	- -
Less than 20'	1715	1902	975	2709	2307	40	27	67
Total	1742	1932	1004	2766	2390	80	89	169

38. The 169 vessel-trips in the channel in 1954 included round-trips of 40 colliers and 31 deep-draft tankers and oil barges. The colliers listed have a length of about 455 feet, a loaded draft of about 29 feet and a cargo capacity of about 11,000 tons. The tankers carrying the bulk of the petroleum commerce are generally of the T-2 type with a length of 523 feet, loaded draft of about 30 feet, and a cargo capacity of 16,500 tons. The drafts of the vessels as stated herein are the normal loaded drafts at the dock.

DIFFICULTIES ATTENDING NAVIGATION

39. The difficulties attending navigation are those of inadequate depths in the channel and maneuvering area. The main ship channel has shoaled along its edges to 22 and 24 feet in the vicinity of Fort Pickering Light, and the shoals have become a hazard to the vessels now using this channel.

40. Mann Rock, with 20 feet of water over it at low water, is located about 0.5 mile east of Juniper Point. It is nearly in the track of vessels approaching Salem Harbor, and is marked by a lighted buoy. It is named after the Isaac T. Mann, a collier which struck it and suffered severe damage in 1930.

41. The channel in the South River has shoaled to the extent that vessels can reach the Pickering Wharf only at high tide. The controlling depth is about 5 feet, although a depth of 8 feet prevails for half the channel width, and the average depth is about 9 feet.

WATER POWER AND OTHER SPECIAL SUBJECTS

42. The waterway is tidal. Matters of water power or flood control are not pertinent to this report. None of the work contemplated would have an adverse effect on wildlife or shellfish.

PLAN OF IMPROVEMENT

43. Consideration has been given to providing, in lieu of the existing 25-foot channel 1500 feet in length, a channel 300 feet wide, and either 30, 32, or 35 feet deep, 1.4, 1.5 or 3.3 miles in length respectively, leading to a terminal approach channel and maneuvering area of similar depth in the vicinity of the Salem Terminal Wharf. Inclusion within the Federal project of the approach channel to the existing terminal wharf as proposed by local interests, would be contrary to Federal policy that such approach channels are the responsibility of the terminal owners. Therefore the plan of improvement herein considered is based on the line of demarcation between the Federal channel and local approach channel as previously established and which marks the present limit of the Federal project. The alternative depths considered would reduce tidal delays now incurred by the deep-draft shipping in the harbor, which is all concentrated in this area of the harbor. The reductions in delays incurred, and shipping

costs occasioned thereby, proportionately increase with the increased channel depth under consideration, and would be entirely eliminated for ships up to 30-foot draft by a channel of 35-foot depth. Similarly a channel of 32 or 35-foot depth would better serve future petroleum commerce which local interests anticipate will be carried in super-tankers of 32 to 34-foot draft.

44. The need for and location of a maneuvering area and turning basin has been given considerable study. The entire deep-draft commerce of Salem Harbor is concentrated at the Salem Terminal Wharf. The history of the past quarter century and the best forecast for the future is that the commerce will continue to be concentrated in this area. Therefore the maneuvering area already dredged by local interests off the Salem Terminal appears to be in the most desirable location.

45. The South Essex Sewerage District owns two sewers which cross the Federal channel, one a 30-inch sewer at an elevation 31 feet below mean low water, the other a 54-inch sewer at an elevation 35 feet below mean low water. The Sewerage District has determined that no alteration of either sewer would be necessitated by deepening the existing channel to a depth of 30 feet. However the Sewerage District does estimate a contingency allowance for possible damage to the 30-inch line in view of the close relationship of the pipe elevation and the proposed channel depth. The Sewerage District considers that provision of a channel 32 feet deep would require lowering of the 30-inch sewer, but no alteration of the 54-inch sewer, whereas provision of a channel 35 feet deep would require lowering of both sewer lines. The Sewerage District indicates that the Town and Cities of the District would probably be opposed to this last alternative, if the District were required to bear the heavier cost occasioned thereby.

46. Consideration has been given to the proposed improvement of the South River channel. Although at the time of the public hearing in 1949 a desire was expressed for deepening of the South River channel from the presently authorized depth of 10 feet to a depth of 14 feet, recent discussions with the only commercial shipper located on the channel indicate that the existing project would be satisfactory if completed and maintained to full project dimensions.

47. Consideration has been given to the proposal of local interests for harbor improvements in connection with construction of a state pier at Salem Harbor. However the need for such an overall harbor development has not been demonstrated, and a project for construction of a state pier has not been initiated by the Commonwealth of Massachusetts.

SHORE LINE EFFECTS

48. The existing Main Ship Channel and the channel in the South River have had no apparent effect upon the shore line of Salem Harbor. The deepening and extension of the Main Ship Channel will have no effect on the adjacent shore lines. The presently authorized 10-foot project for South River contains the provision that no dredging shall be done within 50 feet of any wharf or structure. As a channel of 10-foot depth had been dredged in South River by the Commonwealth of Massachusetts in 1913-1915, its re-dredging now should not adversely affect the adjacent shores.

AIDS TO NAVIGATION

49. The United States Coast Guard has been consulted in regard to establishing aids to navigation. They have stated that no additional aids will be necessary, as the work will require only relocating the existing aids when the improvement is accomplished. No cost will be involved.

ESTIMATES OF FIRST COST

50. Estimates of cost have been prepared for the three plans of improvement considered. These costs have been estimated on the basis of the layout as requested by local interests, which include that portion of the existing project which relates to the Main Ship Channel, and is based on following the natural channel now traversed by harbor navigation. However, dredging costs are allocated to the United States and to local interests in accordance with the separation between Federal project channel and local approach channel as presently established. Dredging quantities for the main channel are in terms of place measurement and provide for dredging to the proposed project depth in ordinary material, plus an allowance of two feet of overdepth. Side-slopes of 1 on 3 were used in the estimates. The unit prices on new work are based on prices prevailing in March 1956 and on removal of material by contract dredging, using a bucket dredge, with disposal of dredged material in deep water at the public dumping ground in Massachusetts Bay. The estimated costs of sewer modifications are based on estimates furnished by the South Essex Sewerage District. The estimated costs of the various considered improvements include allowances for contingencies and engineering, inspections, and overhead. These estimated costs are set forth below:

A. Estimated Cost of 30-Foot Channel

1. Federal - To upstream limit of existing Federal project

a. Dredging 590,000 cubic yards at about \$1.30	\$770,000
b. Removal of Mann Rock to 30-foot depth	10,000
c. Total Federal Cost	<u>\$780,000</u>

2. Non-Federal

a. Wharf Approach Channel and Maneuvering Area - Dredging 190,000 cubic yards at about \$1.30	\$ 250,000
b. Wharf and berth improvements	0
c. Contingency allowance for damages to 30" sewer (owner)	20,000
d. Total Non-Federal Cost	<u>\$ 270,000</u>

3. Total Cost \$1,050,000

B. Estimated Cost of 32-Foot Channel

1. Federal - To upstream limit of existing Federal project

a. Dredging 835,000 cubic yards at about \$1.30	\$1,085,000
b. Removal of Mann Rock to 32-foot depth	15,000
c. Total Federal Cost	<u>\$1,100,000</u>

2. Non-Federal

a. Wharf Approach Channel and Maneuvering Area - Dredging 255,000 cubic yards at about \$1.30	\$ 330,000
b. Wharf and berth improvements	10,000
c. Lowering 30-foot sewer (owner)	115,000
d. Total Non-Federal Cost	<u>455,000</u>

3. Total Cost \$1,555,000

C. Estimated Cost of 35-Foot Channel

1. Federal - To upstream limit of existing Federal project

a. Dredging 1,460,000 cubic yards at about \$1.15	\$1,680,000
b. Removal of Mann Rock to 35-foot depth	20,000
c. Total Federal Cost	<u>\$1,700,000</u>

2. Non-Federal

a. Wharf Approach Channel and Maneuvering Area - Dredging 370,000 cubic yards at about \$1.15	\$ 425,000
b. Wharf and berth improvements	25,000
c. Lowering both 30" and 54" sewers	325,000
d. Total Non-Federal Cost	<u>\$ 775,000</u>

3. Total Cost \$2,475,000

ESTIMATES OF ANNUAL CHARGES

51. The estimated annual carrying charges have been computed on an assumed project life of 50 years with an interest rate of $2\frac{1}{2}$ percent on Federal and non-Federal public investment and 4 percent on private investment. The maintenance cost shown is the additional maintenance which will be required for the improved channel, in excess of that now required by the existing project. The annual carrying charges are summarized in the following table:

	<u>30-Foot Channel</u>	<u>32-Foot Channel</u>	<u>35-Foot Channel</u>
(1) <u>Federal Investment</u>			
(a) Construction Cost (Corps of Engineers)	\$780,000	\$1,100,000	\$1,700,000
(b) Aids to Navigation (Coast Guard)	<u>0</u>	<u>0</u>	<u>0</u>
(c) Total Federal Investment	\$780,000	\$1,100,000	\$1,700,000
(2) <u>Federal Annual Carrying Charges</u>			
(a) Interest	\$ 19,500	\$ 27,500	\$ 42,500
(b) Amortization	8,000	11,300	17,400
(c) Additional annual channel maintenance	<u>2,500</u>	<u>3,200</u>	<u>5,100</u>
(d) Total Federal Annual Carrying Charges	\$ 30,000	\$ 42,000	\$ 65,000
(3) <u>Non-Federal Investment</u>			
(a) Public			
1. Sewer	\$ 20,000	\$ 115,000	\$ 325,000
(b) Private			
1. Approach Channel	250,000	330,000	425,000
2. Wharf and berth	<u>0</u>	<u>10,000</u>	<u>25,000</u>
3. Total private	<u>\$ 250,000</u>	<u>\$ 340,000</u>	<u>\$ 450,000</u>
(c) Total Non-Federal Investment	\$ 270,000	\$ 455,000	\$ 775,000

30-Foot Channel 32-Foot Channel 35-Foot Channel

(4) Non-Federal Annual Carrying Charges

(a) Interest on Item 3(a)	\$ 500	\$ 2,900	\$ 8,100
(b) Interest on Item 3(b)	10,000	13,600	18,000
(c) Amortization on Item 3(a)	200	1,200	3,300
(d) Amortization on Item 3(b)	<u>1,600</u>	<u>2,200</u>	<u>2,800</u>
(e) Total Non-Federal Annual Carrying Charges	\$12,300	\$19,900	\$32,200

(5) Total Annual Carrying Charges

(a) Federal Annual Carrying Charge	\$30,000	\$42,000	\$65,000
(b) Non-Federal Annual Carrying Charge			
1. Public	700	4,100	11,400
2. Private	<u>11,600</u>	<u>15,800</u>	<u>20,800</u>
3. Total	\$12,300	\$19,900	\$32,200
(c) Total Annual Carrying Charges	\$42,300	\$61,900	\$97,200

ESTIMATES OF BENEFITS

52. The improvement of Salem Harbor will be of material benefit to the deep draft shipping of coal and oil which constitutes the overwhelming majority of the present and prospective commerce of Salem Harbor. The proposed Main Ship Channel deepening will eliminate or reduce tidal delays incurred between deep water in the outer harbor and the Salem Terminal Wharf, which serves as a "through-put" terminal for all the deep draft shipping in the harbor. Tidal delays now experienced result from inadequate channel depths for the types of vessels now using the harbor. Inasmuch as the Salem Terminal Wharf receives oil destined for general distribution and consumption, and coal destined principally for use at the New England Power Company's recently constructed nearby power plant, all benefits accruing from the improvement to the upstream limit of the Federal project are considered to be of a general nature.

53. The coal and oil received at the Salem Terminal Wharf is carried in deep-draft colliers and tankers. The colliers have a length of about 455 feet, a draft of about 29 feet and a cargo capacity of about 11,000 tons. About half the receipts are imports, and the remainder are domestic receipts. The tankers carrying the bulk of the petroleum commerce are generally of the T-2 type with a length of about 523 feet, loaded draft of about 30 feet, and a capacity of about 16,500 tons. The drafts of these vessels as stated are the normal loaded drafts at the dock. Oil is delivered to the Pickering Wharf on South River in small tankers and barges with drafts of 9 to 12 feet. These latter vessels are not affected by shoal conditions in the main ship channel.

54. The deep-draft colliers and tankers take maximum benefit of the 9-foot tidal range and usually limit their navigation in the harbor to two hours before and one hour after slack high water, at which period there is 7 to 9 feet of additional channel depth. At this stage of the tide the 25-foot project affords a channel 32 to 34 feet deep. For safe navigation, berths should be 2 feet and channels 5 feet deeper than the registered loaded drafts of the classes of ships concerned. In the present main ship channel at Salem Harbor even at the higher tidal stages there is only 2 to 4 feet of navigation depth in excess of the 30-foot draft of the ships now using the channel. This clearance is not adequate to allow for the various factors affecting ship navigation, such as uneven loading, squat underway, clearance under the keel for maneuverability, minus tides or tides lower than average, and lack of full project depth pending channel maintenance at infrequent intervals. The channel presently used has shoaled to a controlling depth of 24 feet. The vessel traffic is now operating at the highest stages of the tide with less than adequate channel depth, a hazardous condition which will be intensified by further shoaling of the channel.

55. The waterborne coal and oil commerce has increased from about 260,000 tons in 1951 to over 1,180,000 tons in 1955. This increase is in part due to the construction of the new power plant of 160,000 K.W. capacity at Salem Harbor by the New England Power Company and in part to increased oil consumption and a changed pattern of oil distribution. At the present time expansion of the power plant is being planned which will result in further increased commerce in coal.

The power plant construction schedule is as follows:

	Expansion	Total Capacity
Present capacity	-	160,000 kw
1958 Expansion	140,000 kw	300,000 kw
1963 Expansion	140,000 kw	440,000 kw
1975 Expansion	140,000 kw	580,000 kw

Ground was broken March 28, 1956 for the 1958 unit. Studies of the growth of power demand in New England verify the need for the planned expansions of the power plant. Studies of the consumption of petroleum products in the region indicate an expansion in that commerce averaging at least 50 percent over the life of the project. The estimated average annual commerce in coal and oil over the life of the project is arrived at as indicated in the following table:

Annual Harbor Commerce in Tons

Power Plant on Coal

	Power Plant	General Commercial Distribution		Totals		
	Coal	Coal	Oil	Total	Coal	Oil
Present capacity of power plant	450,000	100,000	900,000	1,000,000	550,000	900,000
Expansion in 1958 to 300,000 kw	835,000	100,000	900,000	1,000,000	935,000	900,000
Expansion in 1963 to 440,000 kw	1,170,000	100,000	900,000	1,000,000	1,270,000	900,000
Further future expansion to 580,000 kw	1,475,000	100,000	900,000	1,000,000	1,575,000	900,000

Power Plant on Oil

	Power Plant	General Commercial Distribution		Totals		
	Oil	Coal	Oil	Total	Coal	Oil
Present capacity of power plant	335,000	100,000	900,000	1,000,000	100,000	1,235,000
Expansion in 1958 to 300,000 kw	625,000	100,000	900,000	1,000,000	100,000	1,525,000
Expansion in 1963 to 440,000 kw	920,000	100,000	900,000	1,000,000	100,000	1,820,000
Further future expansion to 580,000 kw	1,210,000	100,000	900,000	1,000,000	2,110,000	2,210,000

56. Varying amounts of vessel traffic would be required to carry the annual commerce under the various alternative conditions of power plant expansion described in the previous paragraph. These estimated future traffic figures are derived by dividing the commerce figures by the fully loaded capacities of the modern colliers and tankers. The future average annual vessel traffic, computed for both alternatives of the power plant use of either coal or oil as a fuel, would be as follows:

	<u>Power Plant on Coal</u>		
	<u>Round Trips</u>		
	T-2		
	<u>Colliers</u>	<u>Tankers</u>	<u>Total</u>
Present Capacity of power plant	50	54	104
Expansion in 1958 to 300,000 kw	85	54	139
Expansion in 1963 to 440,000 kw	115	54	169
Expansion in 1975 to 580,000 kw	143	54	197

	<u>Power Plant on Oil</u>		
	<u>Round Trips</u>		
	T-2		
	<u>Colliers</u>	<u>Tankers</u>	<u>Total</u>
Present Capacity of power plant	9	74	83
Expansion in 1958 to 300,000 kw	9	92	101
Expansion in 1963 to 440,000 kw	9	108	117
Expansion in 1975 to 580,000 kw	9	121	130

57. Local interests have stated their firm conviction that future petroleum commerce will be carried largely in super-tankers of 32 to 34 foot draft. For this reason local opinion is that the channel should be deepened to 32 or 35 feet in anticipation of this transition in type of shipping. The view of the shippers is that a 30-foot channel would in a few years be relatively as inadequate for super-tanker traffic as the present 25-foot channel is for T-2 tanker traffic. Recent tank ship construction has been predominantly of the super-tanker class. Therefore, the bulk of tanker capacity afloat will gradually shift to larger than the T-2 tanker size. Estimates in this report have been made both on the basis of petroleum commerce carried entirely in T-2 tankers and carried half in T-2 tankers and half in 28,000 ton super-tankers of 32-foot draft. Under the latter condition, the table of vessel trips in the preceding paragraph would be revised to show half as many T-2 tanker trips, and the T-2 tanker trips cut out would be replaced by 60 percent of that number of super-tanker trips, the T-2 having a capacity 60 percent that of the 28,000 ton super-tanker. It should be noted that the tables following do not indicate

super-tanker traffic on a channel 25-feet deep, the depth of the existing project, such traffic being considered entirely impracticable

58. The average tidal delay incurred by the colliers and tankers, under the various conditions of channel depth considered, are as follows:

<u>Colliers</u>		<u>29-Foot Draft</u>		<u>Depth Required 34 feet</u>	
(1)	(2)	(3)		(4)	(5)
Channel	Tide	Maximum Delay, (a)		Av. Delay	Av. Delay all
Depth	Req'd	incl. transit		for delayed	vessels
(in feet)		time (b)		vessels	
		(In hours)			
				$(\frac{1}{2} \times \text{Col. 3})$	$(\text{Col. 3} \times \text{Col. 4})$
					12.4 hrs (d)
			<u>Hours</u>		<u>Hours</u>
25(Existing Project)	8(c)	10.2	5.1	$\frac{10.2}{12.4} \times 5.1 =$	4.2
30	4	6.2	3.1	$\frac{6.2}{12.4} \times 3.1 =$	1.5
32	2	4.3	2.1	$\frac{4.3}{12.4} \times 2.1 =$	0.7
35	0	0	0		0

<u>T-2 Tankers</u>		<u>30-Foot Draft</u>		<u>Depth Required 35 feet</u>	
<u>Inbound</u>		(3)		(4)	(5)
(1)	(2)	Maximum Delay, (a)		Av. Delay	Av. Delay all
Channel	Tide	incl. transit		for delayed	vessels
Depth	Req'd	time (b)		vessels	
(in feet)					
				$(\frac{1}{2} \times \text{Col. 3})$	$(\text{Col. 3} \times \text{Col. 4})$
					12.4 hrs
		<u>Hours</u>	<u>Hours</u>		<u>Hours</u>
25 (Existing Project)	8	10.2	5.1	$\frac{10.2}{12.4} \times 5.1 =$	4.2
30	5	7.1	3.5	$\frac{7.1}{12.4} \times 3.5 =$	2.1
32	3	5.3	2.6	$\frac{5.3}{12.4} \times 2.6 =$	1.1
35	0	0	0		0

(a) Scaled from tide curve.

(b) Transit time equals 0.5 hour.

(c) Inadequate, but maximum tide allowance available.

(d) 12.4 hrs = length of tidal cycle.

T-2 Tankers

<u>Outbound</u>		<u>24-Foot Draft</u>	<u>Depth Required 29 feet</u>	
(1)	(2)	(3)	(4)	(5)
Channel	Tide	Maximum Delay, (a)	Av. Delay	Av. Delay all
Depth	Req'd	incl. transit	for delayed	vessels
(in feet)		time (b)	vessels	
			$(\frac{1}{2} \times \text{Col. 3}) (\frac{\text{Col. 3} \times \text{Col. 4}}{12.4 \text{ hrs}})$	
25 (Existing project)	4	$\frac{\text{Hours}}{6.2}$	$\frac{\text{Hours}}{3.1}$	$\frac{6.2}{12.4} \times 3.1 = \frac{\text{Hours}}{1.5}$

30 0

Total T-2 Tanker Average Delay, Inbound and Outbound

<u>Channel Depth</u>	<u>Inbound Delay</u>	<u>Outbound Delay</u>	<u>Total Delay</u>
25 (Existing project)	4.2	1.5	5.7
30	2.1	0	2.1
32	1.1	0	1.1
35	0	0	0

Super-Tankers

<u>Inbound</u>		<u>32-Foot Draft</u>	<u>Depth Required 37 feet</u>	
(1)	(2)	(3)	(4)	(5)
Channel	Tide	Maximum Delay, (a)	Av. Delay	Av. Delay all
Depth	Req'd	incl. transit	for delayed	vessels
(in feet)		time	vessels	
			$(\frac{1}{2} \times \text{Col. 3}) (\frac{\text{Col. 3} \times \text{Col. 4}}{12.4 \text{ hrs}})$	
25				
30	7			3.2
32	5			2.1
35	2			0.7

Super-Tankers Outbound		26-Foot Draft	Depth Required 31 feet	
(1)	(2)	(3)	(4)	(5)
Channel Depth (in feet)	Tide Req'd	Maximum Delay incl. transit time	Av. Delay for delayed vessels	Av. Delay all vessels
			$\left(\frac{1}{2} \times \text{Col. 3}\right) \left(\frac{\text{Col. 3} \times \text{Col. 4}}{12.4 \text{ hrs}}\right)$	

25				
30	1			0.4
32	0			-
35	0			-

Total Super-Tanker Average Delay, Inbound and Outbound

<u>Channel Depth</u>	<u>Inbound Delay</u>	<u>Outbound Delay</u>	<u>Total Delay</u>
25			
30	3.2	0.4	3.6
32	2.1	0.0	2.1
35	0.7	0.0	0.7

59. These tidal delays represent transportation costs dependent upon the hourly cost of the vessels concerned. It is estimated that the average hourly costs at price levels prevailing in the spring of 1956 for the classes of shipping using or that will use Salem Harbor over the life of the project are as follows:

Colliers	\$120
T-2 Tankers	175
Super Tankers	240

For the coal colliers and tankers using Salem Harbor, the tidal delays indicated in the previous tables at the hourly costs for the type of ship concerned represent that part of the future annual transportation cost for this shipping due solely to existing channel limitations.

60. Provision of a channel 30, 32, or 35 feet in depth instead of the present channel of 25 feet will reduce tidal delays as shown in the following tables. These tables are based on the planned expansion of the power plant and includes also the expanded general commerce in coal and petroleum. The first table is based on the petroleum commerce being carried entirely in T-2 tankers, the second is based on the petroleum being carried half in T-2 tankers and half in larger tankers, of 28,000 ton capacity, 32-foot draft.

SALEM HARBOR, MASS. - ESTIMATE OF TIDAL DELAY BENEFITS

PETROLEUM TRAFFIC ENTIRELY IN T-2 TANKERS

POWER PLANT ON COAL												POWER PLANT ON OIL													
Case		Power Plant		General Distribution						Total Commerce				Power Plant		Total Commerce									
		Coal	Trips	Coal	Trips	Oil		Total	Coal	Trips	Tons	Trips	Oil	Trips	Total	Tons	Trips	Coal	Trips	Tons	Trips	Oil	Trips	Total	Tons
						Tons	Trips																		
A	No expansion in power plant 160,000 KW	450,000	41	100,000	9	900,000	54	1,000,000	550,000	50	900,000	54	1,450,000	335,000	20	100,000	9	1,235,000	74	1,335,000					
B	Power plant expansion in 1958 to 300,000 KW	835,000	76	100,000	9	900,000	54	1,000,000	935,000	85	900,000	54	1,835,000	625,000	38	100,000	9	1,525,000	92	1,625,000					
C	" " " " 1963 to 440,000 KW	1,170,000	106	100,000	9	900,000	54	1,000,000	1,270,000	115	900,000	54	2,170,000	875,000	53	100,000	9	1,775,000	107	1,875,000					
D	" " " " 1975 to 580,000 KW	1,475,000	134	100,000	9	900,000	54	1,000,000	1,575,000	143	900,000	54	2,475,000	1,105,000	67	100,000	9	2,005,000	121	2,105,000					

TIDAL DELAYS AND VALUES THEREOF

				POWER PLANT ON COAL				POWER PLANT ON OIL																			
				Case A		Case B		Case C		Case D		Case A		Case B		Case C		Case D									
		Draft	Tide Req'd	Trips	Total Delay	Trips	Total Delay	Trips	Total Delay	Trips	Total Delay	Trips	Total Delay	Trips	Total Delay	Trips	Total Delay	Trips	Total Delay								
			Av. Delay																								
Present 25' Channel																											
Inbound T-2	30'	8'	4.2 Hrs.	54	226.8 Hrs.	54	226.8 Hrs.	54	226.8 Hrs.	54	226.8 Hrs.	74	310.8 Hrs.	92	386.4 Hrs.	108	453.6 Hrs.	121	508.2 Hrs.								
Inbound Collier	29'	8'	4.2 "	50	210.0 "	85	357.0 "	115	483.0 "	143	600.6 "	9	37.8 "	9	37.8 "	9	37.8 "	9	37.8 "								
Outbound T-2	24'	4'	1.5 "	54	81.0 "	54	81.0 "	54	81.0 "	54	81.0 "	74	111.0 "	92	138.0 "	108	162.0 "	121	181.5 "								
30' Channel																											
Inbound T-2	30'	5'	2.1 Hrs.	54	113.4 "	54	113.4 "	54	113.4 "	54	113.4 "	74	155.4 "	92	193.2 "	108	226.8 "	121	254.1 "								
Inbound Collier	29'	4'	1.5 "	50	75.0 "	85	127.5 "	115	172.5 "	143	214.5 "	9	13.5 "	9	13.5 "	9	13.5 "	9	13.5 "								
Outbound T-2	24'	0'	0 "	54	0 "	54	0 "	54	0 "	54	0 "	74	0 "	92	0 "	108	0 "	121	0 "								
* Savings in Tidal Delay Value				Coal 135 Hrs. - \$16,200		Coal 229.5 Hrs. - \$27,500		Coal 310.5 Hrs. - \$37,200		Coal 386.1 Hrs. - \$46,300		Coal 24.3 Hrs. - \$2,900		Coal 24.3 Hrs. - \$2,900		Coal 24.3 Hrs. - \$2,900		Coal 24.3 Hrs. - \$2,900									
				Oil 194.4 " - 34,000		Oil 194.4 " - 34,000		Oil 194.4 " - 34,000		Oil 194.4 " - 34,000		Oil 1266.4 " - 46,600		Oil 1331.2 " - 58,000		Oil 1339.4 " - 68,100		Oil 1435.6 " - 76,200									
				Total \$50,200		Total \$61,500		Total \$71,200		Total \$80,300		Total \$49,500		Total \$60,900		Total \$71,000		Total \$79,100									
32' Channel																											
Inbound T-2	30'	3'	1.1 Hrs.	54	59.4 Hrs.	54	59.4 Hrs.	54	59.4 Hrs.	54	59.4 Hrs.	74	81.4 Hrs.	92	101.2 Hrs.	108	118.8 Hrs.	121	133.1 Hrs.								
Inbound Collier	29'	2'	0.7 "	50	35.0 "	85	59.5 "	115	80.5 "	143	100.1 "	9	6.3 "	9	6.3 "	9	6.3 "	9	6.3 "								
Outbound T-2	24'	0'	0 "	54	0 "	54	0 "	54	0 "	54	0 "	74	0 "	92	0 "	108	0 "	121	0 "								
Savings in Tidal Delay Value				Coal 175 Hrs. - \$21,000		Coal 297.5 Hrs. - \$35,700		Coal 402.5 Hrs. - \$48,300		Coal 500.5 Hrs. - \$60,100		Coal 31.5 Hrs. - \$3,800		Coal 31.5 Hrs. - \$3,800		Coal 31.5 Hrs. - \$3,800		Coal 31.5 Hrs. - \$3,800									
				Oil 1248.4 " - 43,500		Oil 248.4 " - 43,500		Oil 248.4 " - 43,500		Oil 248.4 " - 43,500		Oil 1340.4 " - 52,600		Oil 1423.2 " - 74,100		Oil 1496.8 " - 86,900		Oil 1556.6 " - 97,400									
				Total \$64,500		Total \$79,200		Total \$91,800		Total \$103,600		Total \$63,400		Total \$77,900		Total \$90,700		Total \$101,200									
35' Channel																											
Inbound T-2	30'	0'	0 Hrs.	54	0 Hrs.	54	0 Hrs.	54	0 Hrs.	54	0 Hrs.	74	0 Hrs.	92	0 Hrs.	108	0 Hrs.	121	0 Hrs.								
Inbound Collier	29'	0'	0 "	50	0 "	85	0 "	115	0 "	143	0 "	9	0 "	9	0 "	9	0 "	9	0 "								
Outbound T-2	24'	0'	0 "	54	0 "	54	0 "	54	0 "	54	0 "	74	0 "	92	0 "	108	0 "	121	0 "								
Savings in Tidal Delay Value				Coal 210.0 Hrs. - \$25,200		Coal 357.0 Hrs. - \$42,800		Coal 483.0 Hrs. - \$58,000		Coal 600.6 Hrs. - \$72,100		Coal 37.8 Hrs. - \$4,500		Coal 37.8 Hrs. - \$4,500		Coal 37.8 Hrs. - \$4,500		Coal 37.8 Hrs. - \$4,500									
				Oil 307.8 " - 53,900		Oil 307.8 " - 53,900		Oil 307.8 " - 53,900		Oil 307.8 " - 53,900		Oil 1421.8 " - 73,800		Oil 1524.4 " - 91,800		Oil 1615.6 " - 107,700		Oil 1689.7 " - 120,700									
				Total \$79,100		Total \$96,700		Total \$111,900		Total \$126,000		Total \$78,300		Total \$96,300		Total \$112,200		Total \$125,200									

* T-2 \$175/hour
Collier \$120/hour

SALEM HARBOR, MASS.

ESTIMATE OF BENEFITS BASED ON OIL 1/2 IN SUPERS, 1/2 IN T-2S

Super 28,000T 32' Draft Inbd, 26' Outbd
T - 2 16,500T 30' Draft Inbd, 24' Outbd

Power Plant on Coal												Power Plant on Oil				Power Plant on Oil				Power Plant on Oil			
	Draft	Tide Reg'd	Av. Delay (Hrs)	Case A		Case B		Case C		Case D		Case A		Case B		Case C		Case D		Tanker Trips Due to Power Plant Only			
				Trips	Total Delay (Hrs)	Trips	Total Delay (Hrs)	Trips	Total Delay (Hrs)	Trips	Total Delay (Hrs)	Trips	Total Delay (Hrs)	Trips	Total Delay (Hrs)	Trips	Total Delay (Hrs)	Trips	Total Delay (Hrs)	Trips	Total Delay (Hrs)	1/2 T - 2	1/2 Supers
Present 25' Channel																							
Inbound T-2	30'	8'	4.2	54	226.8	54	226.8	54	226.8	54	226.8	74	310.8	92	386.4	107	449.4	121	508.2	A	335,000T	10	6
Inbound Collier	29'	8'	4.2	50	210.0	85	357.0	115	483.0	143	600.6	9	37.8	9	37.8	9	37.8	9	37.8	B	625,000T	19	11
Outbound T-2	24'	4'	1.5	54	81.0	54	81.0	54	81.0	54	81.0	74	111.0	92	138.0	107	160.5	121	181.5	C	875,000T	27	16
30' Channel																							
Inbound Super	32'	7'	3.2	16	51.2	16	51.2	16	51.2	16	51.2	22	70.4	27	86.4	32	102.4	36	115.2	D	1,105,000T	34	20
Inbound T-2	30'	5'	2.1	27	56.7	27	56.7	27	56.7	27	56.7	37	77.7	46	96.6	54	113.4	61	128.1				
Inbound Collier	29'	4'	1.5	50	75.0	85	127.5	115	172.5	143	214.5	9	13.5	9	13.5	9	13.5	9	13.5				
Outbound Super	26'	1'	0.4	16	6.4	16	6.4	16	6.4	16	6.4	22	8.8	27	10.8	32	12.8	36	14.4				
Outbound T-2	24'	0	0	27	0	27	0	27	0	27	0	37	0	46	0	54	0	61	0				
Savings in Tidal Delay (In hours and dollar value)																							
*Supers				-57.6	-13,800	-57.6	-13,800	-57.6	-13,800	-57.6	-13,800	-79.2	-19,000	-97.2	-23,300	-115.2	-27,600	-129.6	-31,100	* Supers		\$240/hr	
*T-2s				251.1	43,900	251.1	43,900	251.1	43,900	251.1	43,900	344.1	60,200	427.8	74,900	496.5	86,900	561.6	98,300	* T - 2s		\$175/hr	
*Colliers				135.0	16,200	229.5	27,500	310.5	37,300	386.1	46,300	24.3	2,900	24.3	2,900	24.3	2,900	24.3	2,900	* Colliers		\$120/hr	
Total					\$46,300		\$57,600		\$67,400		\$76,400		44,100		54,500		62,200		70,100				
32' Channel																							
Inbound Super	32'	5'	2.1	16	33.6	16	33.6	16	33.6	16	33.6	22	46.2	27	56.7	32	67.2	36	75.6				
Inbound T-2	30'	3'	1.1	27	29.7	27	29.7	27	29.7	27	29.7	37	40.7	46	50.6	54	59.4	61	67.1				
Inbound Collier	29'	2'	0.7	50	35.0	85	59.5	115	80.5	143	100.1	9	6.3	9	6.3	9	6.3	9	6.3				
Outbound Super	26'	0	0	16	0	16	0	16	0	16	0	22	0	27	0	32	0	36	0				
Outbound T-2	24'	0	0	27	0	27	0	27	0	27	0	37	0	46	0	54	0	61	0				
Savings in Tidal Delay (In hours and dollar value)																							
*Supers				-33.6	-8,100	-33.6	-8,100	-33.6	-8,100	-33.6	-8,100	-46.2	-11,100	-56.7	-13,600	-67.2	-16,100	-75.6	-18,100				
*T-2s				278.1	48,700	278.1	48,700	278.1	48,700	278.1	48,700	381.1	66,700	473.8	82,900	550.5	96,300	622.6	109,000				
*Colliers				175.0	21,000	297.5	35,700	402.5	48,300	500.5	60,100	31.5	3,800	31.5	3,800	31.5	3,800	31.5	3,800				
Total					\$61,600		\$76,300		\$88,900		\$100,700		59,400		73,100		84,000		94,700				
35' Channel																							
Inbound Super	32'	2'	0.7	16	11.2	16	11.2	16	11.2	16	11.2	22	15.4	27	18.9	32	22.4	36	25.2				
Inbound T-2	30'	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Inbound Collier	29'	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Outbound Super	26'	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Outbound T-2	24'	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Savings in Tidal Delay (In hours and dollar value)																							
*Supers				-11.2	-2,700	-11.2	-2,700	-11.2	-2,700	-11.2	-2,700	-15.4	-3,700	-18.9	-4,500	-22.4	-5,400	-25.2	-6,000				
*T-2s				307.8	53,900	307.8	53,900	307.8	53,900	307.8	53,900	421.8	73,800	524.4	91,800	609.9	106,700	689.7	120,700				
*Colliers				210.0	25,200	357.0	42,800	483.0	58,000	600.6	72,100	37.8	4,500	37.8	4,500	37.8	4,500	37.8	4,500				
Total					\$76,400		\$94,000		\$109,200		\$123,300		74,600		91,800		105,800		119,200				

61. The average annual benefits as computed in the preceding paragraphs may be summarized as follows:

Based on Petroleum Entirely in T-2 Tankers

	<u>Power Plant on Coal</u>			
	Present	1958	1963	1975
	(KW)	(KW)	(KW)	(KW)
Power Plant Capacities	160,000	300,000	440,000	580,000
30-foot channel	50,200	61,500	71,200	80,300
Increment 30 to				
32-foot channel	14,300	16,700	20,600	23,300
32-foot channel	64,500	78,200	91,800	103,600
Increment 32 to				
35-foot channel	14,600	18,500	20,100	22,400
35-foot channel	79,100	96,700	111,900	126,000

Based on Petroleum Carried Half in T-2s, Half in 28,000T Supers

30-foot channel	46,300	57,600	67,400	76,400
Increment 30 to				
32-foot channel	15,300	18,700	21,500	24,300
32-foot channel	61,600	76,300	88,900	100,700
Increment 32 to				
35-foot channel	14,800	17,700	20,300	22,600
35-foot channel	76,400	94,000	109,200	123,300

Based on Petroleum Entirely in T-2 Tankers

	<u>Power Plant on Oil</u>			
	Present	1958	1963	1975
Power Plant Capacities	160,000	300,000	440,000	580,000
30-foot channel	49,500	60,900	71,000	79,100
Increment 30 to				
32-foot channel	13,900	17,000	18,700	22,100
32-foot channel	63,400	77,900	89,700	101,200
Increment 32 to				
35-foot channel	14,900	18,400	22,500	24,000
35-foot channel	78,300	96,300	112,200	125,200

Based on Petroleum Carried Half in T-2s, Half in 28,000T Supers

30-foot channel	44,100	54,500	62,200	70,100
Increment 30 to				
32-foot channel	15,300	18,600	21,800	24,600
32-foot channel	59,400	73,100	84,000	94,700
Increment 32 to				
35-foot channel	15,200	18,700	21,800	24,500
35-foot channel	74,600	91,800	105,800	119,200

62. Study of the comparative benefits due solely to reduction of shipping delays in the harbor occasioned by waiting for tidal stages to afford sufficient depth of water in the channel reveals several factors worthy of note. With petroleum commerce carried in T-2 tankers, the benefits due to reduction of tidal delays are practically equal regardless of whether the power plant uses coal or oil as a fuel. A shift to the more economical bulk petroleum carrier, the 28,000 ton super-tanker, tends to reduce the tidal delay costs to petroleum shipping, but the reduction generally ranges less than 10 percent. This shift in size of petroleum carriers tends to slightly reduce benefits due to reduction of port tidal delays by channel deepening, and this reduction in tidal delay benefits would be somewhat greater if the power plant uses oil as a fuel rather than coal. Again the differences are minor, generally less than 10 percent. A significant fact however is that use of super-tankers increases the incremental benefit of the 30 to 32-foot channel deepening by about 10 percent for all variables of power plant expansion and use of coal or oil by the power plant.

63. In addition to the benefits due to reduction of port tidal delays that would be possible by channel deepening, there are also the much greater benefits due to enabling use of the larger tanker, with attendant massive economies. The 28,000 ton supertanker coming into predominance in the petroleum tank fleet carries 60 percent more petroleum at about 30 percent greater cost than with the T-2 tanker. The annual benefits to petroleum commerce in Salem Harbor range at about \$1.20 a ton, or \$0.20 a barrel for all petroleum carried in supertankers. Transition of as little as 10 percent of the petroleum traffic to supertankers would provide annual benefits estimated at \$108,000, about equal to the total benefits derived from reduction of port tidal delays. These large benefits due to port capability to receive petroleum in supertankers accrue to any channel of depth sufficient to permit use of such supertankers. With the tidal range at Salem a 30-foot channel is considered practicable of navigation by these supertankers. The transition to supertankers also increases the favorability of further channel deepening to a 32-foot depth, but does not materially affect the incremental benefits beyond that depth.

COMPARISON OF BENEFITS AND COSTS

64. A comparison of benefits and costs for the various channel depths considered, under the different conditions of harbor commerce, follows:

COSTS

Channel Depths

	30	30-32	32	32-35	35
First Cost					
Federal	\$ 780,000	\$320,000	\$1,100,000	\$600,000	\$1,700,000
Local	270,000	185,000	455,000	320,000	775,000
Total	\$1,050,000	\$505,000	\$1,555,000	\$920,000	\$2,475,000
Annual Charges					
Federal	\$ 30,000	\$ 12,000	\$ 42,000	\$ 23,000	\$ 65,000
Local	12,300	7,600	19,900	12,300	32,200
Total	\$ 42,300	\$ 19,600	\$ 61,900	\$ 35,300	\$ 97,200

Benefits Due Solely to Reduction of Port Tidal Delays
Based on Petroleum Being Carried Entirely in T-2 Tankers

	<u>Benefits</u>	<u>B/C</u>	<u>Benefits</u>	<u>B/C</u>	<u>Benefits</u>	<u>B/C</u>	<u>Benefits</u>	<u>B/C</u>	<u>Benefits</u>	<u>B/C</u>
		<u>Ratio</u>		<u>Ratio</u>		<u>Ratio</u>		<u>Ratio</u>		<u>Ratio</u>
<u>Power Plant on Coal</u>										
Case A	50,200	1.2	14,300	0.7	64,500	1.0	14,600	0.4	79,100	0.8
B	61,500	1.5	16,700	0.9	78,200	1.3	18,500	0.5	96,700	1.0
C	71,200	1.7	20,600	1.1	91,800	1.5	20,100	0.6	111,900	1.2
D	80,300	1.9	23,300	1.2	103,600	1.7	22,400	0.6	126,000	1.3

Power Plant On Oil

Case A	49,500	1.2	13,900	0.7	63,400	1.0	15,000	0.4	78,400	0.8
B	60,900	1.4	16,900	0.9	77,800	1.3	18,500	0.5	96,300	1.0
C	71,000	1.7	18,700	1.0	89,700	1.4	22,500	0.6	112,200	1.2
D	79,100	1.9	22,100	1.1	101,200	1.6	24,000	0.7	125,200	1.3

Based on Half Petroleum in Super-Tankers, Half in T-2 Tankers

Power Plant on Coal

Case A	46,300	1.3	15,300	0.8	61,600	1.0	14,800	0.4	76,400	0.8
B	57,600	1.4	18,700	1.0	76,300	1.2	17,700	0.5	94,000	1.0
C	67,400	1.6	21,500	1.1	88,900	1.4	20,300	0.6	109,200	1.1
D	76,400	1.8	24,300	1.2	100,700	1.6	22,600	0.6	123,300	1.3

Power Plant On Oil

Case A	44,100	1.0	15,300	0.8	59,400	1.0	15,200	0.4	74,600	0.8
B	54,500	1.3	18,600	1.0	73,100	1.2	18,700	0.5	91,800	0.9
C	62,200	1.5	21,800	1.1	84,000	1.4	21,800	0.6	105,800	1.1

65. In addition to the benefits due to reduction of tidal delays, there are much larger benefits that would accrue to channel deepening to any of the three alternative depths of 30, 32 and 35 feet considered in this report. These larger benefits would be due to enabling use of supertankers in the harbor commerce, not now practicable because of channel limitations. A shift of only 10 percent in the commerce from T-2 tankers to supertankers adds \$108,000 to the annual benefits for all variables of channel depth. A greater percentage shift, or transition of power plant fuel from coal to oil, would further increase this annual benefit due to savings in transportation costs of the two types of ship involved. The benefit-cost ratios due solely to this assumed minimum change of 10 percent in character of shipping are 2.6, 1.7 and 1.1 respectively for the 30, 32, and 35-foot proposed channel depths. These additional benefit cost ratios added to those due solely to reduction in port tidal delays would result in total benefit-cost ratios for the 30, 32, and 35-foot channels of 4.5, 3.3, and 2.4 respectively. The incremental ratios for the 30 to 32 foot deepening, and 32 to 35 foot deepening, remain unchanged at 1.2 and 0.6.

66. No local cash contribution toward the cost of the improvement should be required as the benefits to be derived are general in character. However, local interests have provided and maintained an approach channel to the existing terminal in accordance with the requirements of local cooperation as set forth in the existing project. The benefits due to the proposed modification of the Federal project can only be realized by an equivalent deepening of the approach channel. Therefore local interests should be required to provide an equivalent approach channel.

COORDINATION WITH OTHER AGENCIES

67. All Federal, State and local agencies interested in the development and use of waterways in general, and Salem Harbor in particular, were advised of the public hearing which was held on September 22, 1949. The project was discussed several times with the United States Coast Guard. The Massachusetts Departments of Commerce and Public Works were consulted during the study.

The South Essex Sewerage District furnished estimates of the effect of the proposed improvement upon the existing sewers. Local interests have furnished satisfactory evidences of willingness and ability to meet the requirements of local cooperation.

DISCUSSION

68. Salem Harbor is one of the four harbors which are arms of the large, irregular indentation in the shore of Massachusetts Bay, 11 miles southwesterly from Cape Ann and 12 miles northeasterly of Boston Harbor entrance. The main ship channel with natural depths in excess of 35 feet leads from the open ocean in a westerly direction between Bakers and Great Misery Islands to the outer harbor. From a point in the outer harbor about 2 miles west of Bakers Island to the Salem Terminal Wharf, a distance of about 3.6 miles, the channel has depths decreasing from 35 to 25 feet. In the outer 1.7 miles of this channel natural depths decrease from 35 to 32 feet, and within a further distance of 500 feet up the harbor channel the natural depths reduce to 30 feet. The inner 1.8 miles of channel have depths of 25 feet or more, over a mile of this length being natural channel, and the remaining inner portion having been dredged 25 feet deep and 300 feet wide by the United States and local interests. An approach to the center of the City of Salem is provided by South River which extends westerly from Derby Wharf, located about 3,000 feet southwest of Salem Terminal Wharf.

69. The Main Ship Channel serves the City of Salem, which is the trading center for a population of over 184,000 living in the North Shore area extending from Lynn to Cape Ann. The area is a highly developed manufacturing center producing electric and radio apparatus, boots and shoes, leather, and foundry and machine products.

70. Salem Harbor was originally improved under the River and Harbor Act of March 3, 1873, which authorized the dredging to 8 feet at mean low water, of an approach channel to South River. Subsequent acts authorized further improvement of the South River Channel and the dredging of the Main Ship Channel to 25 feet at mean low water from the 25-foot depth curve in the inner harbor to a point 1500 feet from the Salem Terminal Wharf, a length of about 1500 feet. The latter channel was completed in 1931 and no maintenance has been performed. The controlling depth in the Main Ship Channel is now 24 at mean low water.

71. The principal commerce in Salem Harbor is the transportation of coal and petroleum products. For the period 1945 through 1951, inclusive, the tonnage averaged 318,000 tons annually, of which about

275,000 tons was coal and about 43,000 tons was oil. Since 1951, the tonnage has increased to a total of over 1,180,000 tons in 1955, of which about 575,000 tons was coal and about 604,000 tons was oil. This present commerce consists of about 465,000 tons of coal and 20,000 tons of oil for the power plant constructed in 1951, and 92,000 tons of coal and 578,000 tons of oil for industrial and commercial distribution. The slight differences between these figures of disposition of coal and oil and the figures quoted earlier in the paragraph showing receipts of coal and oil are unallocated additions to the stockpiles. This increase in total annual tonnage therefore is due to two separate causes, only indirectly related. The general commercial and industrial commerce in fuels has approximately doubled, from 318,000 tons to 600,000 tons. There has been a marked shift in the type of fuel making up this commerce, from 85 percent coal, 15 percent oil, to nearly 90 percent oil, and about 10 percent coal. On the other hand, the present commerce in coal and oil to the power plant is entirely a new commerce, not existing prior to 1951. The combination of the increased commerce in fuels for industrial and commercial distribution, and the commerce in fuels to the power plant, results in a total net increase of about 300,000 tons of coal, more than doubling the former commerce in that commodity, and an increase of over 550,000 tons of oil, the present commerce being roughly 14 times the former commerce in this commodity.

72. The greater part of the increase in commerce in fuels for commercial and industrial distribution is considered to represent a shift in distribution pattern rather than increased consumption in the area. This shift is not expected to continue to increase the commerce at the rate of the past few years. Based on studies of the long range increase in the consumption of petroleum fuels to be expected in the State and region, an average increase over the 50 year life of the project of 50 percent over the present petroleum commerce has been used in estimating benefits accruing to the project. Regional studies have also been made of expansion in electric power requirements, which in turn can be directly related to expansion in fuel consumption in generating the power. These studies indicate an average annual increase of about 5 percent accumulative or compounded, such rate of increase expected to be maintained at least for the life of this project. The expansion of the Salem Power plant as planned by the New England Power Company for 1958 and 1963 appears to conform to this expanded demand, and it would appear that the demand will far exceed the third expansion for this plant planned for 1975. These three stages of planned expansion of the power plant would increase the annual coal commerce of the port by about 385,000 tons in 1958, again in 1963, and again in 1975. These increases result in average increases

in commerce over the entire life of the project of about 385,000 tons, 335,000 tons, and 305,000 tons, respectively. Since the power plant is designed to use either coal or oil, the effects upon benefits of a possible shift to oil have been analyzed. Although the oil tonnage required to produce thermal equivalent is only 75% that of required coal tonnage, it has been found that other factors cancel the decreased tonnage if the power plant shifted to oil, and that no net decrease in benefits would therefore occur if the oil is carried in T-2 tankers. If the petroleum is carried half in supertankers, a minor decrease in benefits of less than 10 percent occurs. The benefits accruing to the project have been computed for the present capacity of the power plant, and for each of the three stages of expansion of its capacity as now planned by the New England Power Company.

73. Prior to 1951, the draft of vessels using Salem Harbor did not exceed 25 feet. Since the development of the harbor as a major oil port and the construction of the new power plant adjacent to Salem Terminal Wharf, the majority of deep-draft vessels using the harbor draw between 29 and 31 feet. Colliers in use have a length of about 453 feet, a draft of about 29 feet, and a cargo capacity of about 11,000 tons. Tankers carrying the bulk of the petroleum commerce are generally of the T-2 type, with a length of about 523 feet, a loaded draft of about 30 feet, and a cargo capacity of about 16,000 tons. Tank ship construction in recent years has been predominantly in larger than T-2 tanker size. The harbor shipping interests state logically that with the replacement of the T-2 tanker, the oil commerce will be carried in supertankers. The more common size of these larger tankers is about 28,000 ton capacity, 32-foot draft.

74. The Salem Terminal Wharf, the only deep-draft terminal in Salem Harbor, is located at the head of the natural deep water channel into the harbor, and has become a "through-put" terminal for local fuel distributors. At the present time, about 15 percent of the coal received, and virtually all the oil received is destined for distribution to outlets over a large area. The wharf is the source of supply for two fuel distributing companies and for the New England Power Company. The Pocahontas Fuel Company, Incorporated, operates the coal terminal and distributes commercial oil, and the George W. Pickering Company sells and trucks bituminous coal in the immediate area. The New England Power Company electric power station, located adjacent to the Salem Terminal Company's Wharf, presently uses coal but is designed to use either coal or oil.

75. All bituminous coal received in the harbor is brought to the Salem Terminal Wharf in deep-draft colliers drawing up to 29 feet. Oil is brought to the Salem Terminal Wharf in T-2 tankers drawing 30 feet, and to Pickering Wharf on South River in small self-propelled barges. Future intercoastal and foreign petroleum traffic is expected to be at least partially in supertankers. Present depths in the Main Ship Channel restrict its use by the majority of deep-draft colliers and T-2 tankers to the period of two hours before to one hour after high water, and prevent the use of supertankers. Deepening of the Main Ship Channel would reduce or eliminate tidal delays presently incurred by the deep-draft colliers and T-2 tankers entering Salem Harbor, thus reducing the costs of fuel transportation to the area. The alternative depths of channel improvement considered will enable the use of supertankers, with the large shipping benefits attending use of these tankers. Inasmuch as oil and coal transported to the harbor are destined for commercial and industrial uses, for general retail distribution, and for use by the power station of the New England Power Company, benefits accruing from the deepening of the channel may be considered to be general in nature. Also since electric power rates in Massachusetts are subject to regulation by the State Department of Public Utilities, channel improvements which lower the cost of fuel for the adjacent power station will ultimately affect power rates in the area.

76. Local interests have requested the modification of the existing project in Salem Harbor to provide a channel depth of 30, 32, or 35 feet and preferably to either 32 or 35 feet, to a point 100 feet from the face of the Salem Terminal Wharf, and the removal of Mann Rock, located about 0.5 mile east of Juniper Point. That part of the local proposal concerning extending the Federal project from its present limit 1500 feet off Salem Terminal to the terminal face is considered to be contrary to established Federal policy that approach channels to waterfront terminals are the responsibility of local interests. At the hearing conducted in 1949, local interests further requested the modification of the existing project to provide for the deepening of the South River Channel. Since that time, however, local interests have modified their requests, and now desire only the completion and maintenance of the South River Channel to authorized project depth of 10 feet at mean low water.

77. Consideration has been given to the provision of 30, 32, and 35 foot channels, each with a width of 300 feet, and each extending from the respective depth curve in the outer harbor to a point about 1500 feet from the face of the Salem Terminal Wharf where the present 25-foot Federal project ends. Consideration has also been given to the removal of Mann Rock. The proposed improvement of the Federal channel contemplates and is necessarily dependent upon equivalent improvement by local interests of the terminal approach channel.

78. Salem Harbor is crossed by two sewer lines which pass under the Main Ship Channel. A 54-inch cast-iron pipe force main extends easterly from Juniper Point and is laid with the top of the pipe 35 feet below the plane of mean low water in the section below the Main Ship Channel. A 30-inch cast-iron force main extends from Juniper Cove and is laid with the top of the pipe 31 feet below the plane of mean low water in the section below the Main Ship Channel. The owners of these sewer lines state that it will not be necessary for them to lower either line in the event of an improvement of the present channel to 30 feet at mean low water. However, they state that dredging to this depth would leave the 30-inch pipe with practically no cover over it and some damage might be done to the line. They estimate this damage should not exceed \$20,000 and this amount has been used in the estimate of first cost. Dredging to 32 feet at mean low water would necessitate the lowering of the 30-inch line at an estimated cost to the owners of \$115,000. Dredging to 35 feet would necessitate the lowering of both sewer lines at an estimated cost to the owners of \$325,000.

79. The various proposals for channel deepening require assumption by local interests of major costs to make the harbor improvements effective. The costs of the alternative improvements considered, and their allocation, are summarized as follows:

	<u>30-Foot Channel</u>	<u>32-Foot Channel</u>	<u>35-Foot Channel</u>
<u>First Costs</u>			
United States	\$ 780,000	\$1,100,000	\$1,700,000
Local Interests			
Channel and wharf	250,000	340,000	450,000
Sewer	20,000	115,000	325,000
Total local interests	<u>\$ 270,000</u>	<u>\$ 455,000</u>	<u>\$ 775,000</u>
Total	\$1,050,000	\$1,555,000	\$2,475,000
<u>Annual Charges</u>			
United States	\$ 30,000	\$ 42,000	\$ 65,000
Local Interests	12,300	19,900	32,200
Total	<u>\$ 42,300</u>	<u>\$ 61,900</u>	<u>\$ 97,200</u>

It will be noted that about 30 percent of the total costs are to be borne by local interests. To date local interests have expended \$426,000 on the deep-draft channel improvement as compared to expenditures by the United States of \$45,000. Therefore a comparison of total United States and local expenditures for channel improvements, including the presently proposed channel deepening, would be as follows:

	<u>30-Foot Channel</u>	<u>32-Foot Channel</u>	<u>35-Foot Channel</u>
United States	\$ 825,000	\$1,145,000	\$1,745,000
Local Interests	<u>696,000</u>	<u>881,000</u>	<u>1,201,000</u>
Total	\$1,521,000	\$2,026,000	\$2,946,000

In addition local interests expended \$410,000 in 1951 on wharf construction which would make total local expenditures about equal to or exceeding the total United States expenditure under any of the above alternative channel improvements.

80. The benefits to be derived from the various channel improvements vary widely, depending on several circumstances, including the depth of channel provided, stage of power plant expansion, the use of coal or oil as a fuel by the power plant, and the extent of shifting of petroleum commerce from the T-2 tanker to the larger tanker such as the 28,000 ton supertanker. The benefits to be derived are of two general types, (1) reduction in port tidal delays, and (2) saving in transportation cost due to enabling use of the larger more economical supertanker. Of these two types of annual benefits, the former range from \$44,100 to \$126,000, dependent on channel depth provided, stage of power plant expansion, and use of coal or oil as a fuel by the power plant. The latter annual benefits, due to anticipated transition to the supertanker made possible by the proposed channel improvement, are much larger in magnitude, a shift of 10 percent in petroleum commerce to supertankers resulting in an annual benefit of \$108,000 if the power plant burns coal as a fuel, or up to \$240,000 on the same percentage shift if the power plant burns oil. The ratios of benefits to costs vary similarly, and may be summarized briefly as follows:

	<u>30-Foot Channel</u>	<u>32-Foot Channel</u>	<u>35-Foot Channel</u>
<u>Power Plant on Coal</u>			
Reduction Tidal Delays	1.8	1.6	1.3
10% Shift to Supertankers	<u>2.6</u>	<u>1.7</u>	<u>1.1</u>
Total	4.4	3.3	2.4
<u>Power Plant on Oil</u>			
Reduction in Tidal Delays	1.7	1.5	1.2
10% Shift to Supertankers	<u>5.7</u>	<u>2.9</u>	<u>2.5</u>
Total	7.4	5.4	3.7

81. Selection of the proper channel depth to be recommended rests largely upon a comparison of the additional costs and benefits resulting from the various channel depths considered. It is obvious, of course, that the 30-foot channel would be least expensive. The comparison is summarized below:

	<u>Channel Deepening</u>	
	<u>From 30 to 32 Feet</u>	<u>From 32 to 35 Feet</u>
<u>Additional First Cost</u>		
United States	\$320,000	\$600,000
Local Interests		
Channel and wharf	90,000	110,000
Sewer	95,000	210,000
Total local interests	\$185,000	\$320,000
Total	\$505,000	\$920,000
<u>Additional Annual Charges</u>		
United States	\$ 12,000	\$ 23,000
Local Interests	7,600	12,300
Total	\$ 19,600	\$ 35,300
<u>Additional Benefits</u>		
<u>Power Plant on Coal</u>		
Reduction Tidal Delays	\$ 24,300	\$ 22,600
10% Shift to Supertankers	0	0
Total	\$ 24,300	\$ 22,600
<u>Power Plant on Oil</u>		
Reduction Tidal Delays	\$ 24,600	\$ 24,500
10% Shift to Supertankers	0	0
Total	\$ 24,600	\$ 24,500
<u>Incremental Benefit-Cost Ratios</u>		
Power Plant on Coal	1.2	0.6
Power Plant on Oil	1.3	0.7

82. Local interests have proposed the construction of a state pier at Salem Harbor to meet the needs of the expanding fish industry of the surrounding area. A need for harbor development to serve such a terminal has not been demonstrated and there are no available statistics nor data furnished which could be used as a basis for the evaluation of the requirements for instituting a state pier project. The majority of local interests have stated that the provision of

of additional channel facilities in Salem Harbor was necessary before any consideration could be given to the erection of a state pier.

CONCLUSION

83. The Division Engineer concludes that the existing 25-foot channel in Salem Harbor is inadequate for the type of ships presently engaged in the petroleum and coal trade, and precludes use of the supertankers which are rapidly replacing the T-2 tanker. He further concludes that the channel depth should be 32 feet, as indicated by the favorable ratio of benefits to costs for the increments of channel depth up to that depth, and unfavorable ratio of benefits to costs for further deepening beyond that depth. The Division Engineer concludes that the modification of the project should be to the same limit as the existing Federal project, in the center of the harbor about 1500 feet off Salem Terminal Wharf, and for the improvement to be effective requires and is contingent upon provision by local interests of an equivalent terminal approach channel and maneuvering area. The Division Engineer finally concludes that the total estimate of cost to the United States of \$1,100,000, with no additional aids to navigation required, should be appropriated equally in two fiscal years to enable most economical construction of the project.

RECOMMENDATION

84. The Division Engineer recommends that the existing project for Salem Harbor, Massachusetts, be modified to provide a channel 32 feet deep at mean low water and generally 300 feet wide extending about 1.5 miles from deep water in the outer harbor to the limit of the existing Federal project about 1500 feet off Salem Terminal Wharf, and removal of Mann Rock to the same depth, contingent upon provision by local interests of a terminal approach channel and maneuvering area of equivalent depth, all as shown on the maps accompanying this report, at an estimated cost, to be borne by the United States, of \$1,100,000 for new work, without additional aids to navigation being required. The cost to the United States of annual maintenance in addition to that now required is estimated to be \$3,200. The project modification is recommended subject to the further condition that local interests provide without cost to the United States all lands, easements, and rights-of-way necessary for construction of the project, and hold and save the United States free from damages due to construction and maintenance of the improvement.

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